Executive Summary

This report summarizes findings from the US Environmental Protection Agency's (EPA) hydraulic fracturing study. The goal of this first phase of the study was to determine if a threat to public health as a result of underground sources of drinking water (USDW) contamination from hydraulic fracturing of coalbed methane (CBM) wells (herein known as hydraulic fracturing) exists, and if so, is it high enough to warrant further study. Based on the information collected, the potential threats to USDWs posed by hydraulic fracturing of CBM wells appear to be low and do not justify additional study.

This study is the most thorough effort conducted to review any impacts to public health as a result of USDW contamination from hydraulic fracturing. If risks from hydraulic fracturing of CBM wells were significant, we would expect to find instances of water well contamination from the practice. Instead, thousands of CBM wells are fractured annually and yet EPA did not find persuasive evidence that any drinking water wells had been contaminated by CBM hydraulic fracturing.

EPA also evaluated the theoretical potential for hydraulic fracturing to impact drinking water wells. In some cases, constituents of concern (see section ES-7) are injected into USDWs during the course of normal fracturing operations. However, EPA's determination is that the threat of contamination of drinking water supplies is low because concentrations are diminished by the ground water production aspect of coalbed methane development. Studies have found no observed breach of confining layers from hydraulically created fractures, consistent with theoretical understanding of fracturing behavior.

Although the threat to public health from hydraulic fracturing appears to be low, it may be feasible and prudent for industry to remove any threat whatsoever from injection of fluids. The use of diesel fuel in fracturing fluids by some companies introduces the majority of constituents of concern to USDWs. Water-based alternatives exist and from an environmental perspective, these water-based products are preferable.

ES-1 How Does CBM Play a Role in the Nation's Energy Demands?

Coalbed methane mining began as a safety measure in underground coalmines to reduce the explosion hazard posed by methane gas (Elder and Deul, 1974). In 1980, the U.S. Congress enacted a tax credit for non-conventional fuels production, including coalbed methane production, as part of the Crude Oil Windfall Profit Act. In 1984, there were fewer than 100 coalbed wells in the U.S. By 1990, almost 8,000 coalbed wells had been drilled nationwide (Pashin and Hinkle, 1997). In 1996, coalbed methane production in 12 states totaled about 1,252 billion cubic feet, accounting for approximately seven percent of U.S. gas production (U.S. Department of Energy, 1999). According to the U.S. Department of Energy, natural gas demand is expected to increase at least 45% in the next 20 years (U.S. Department of Energy, 1999). The rate of coalbed methane production is also expected to increase in response to the growing demand.

EPA reviewed geology in eleven basins, illustrated in Figure ES-1, throughout the U.S. The most actively producing basins are highlighted in red on the map and include the Powder River Basin in Wyoming and Montana, the San Juan Basin in Colorado and New Mexico, and the Black Warrior Basin in Alabama. Hydraulic fracturing is or has been used to stimulate CBM wells in all basins, although not frequently in the Powder River Basin. Table ES-1 lists the estimated number of active producing wells, production volume of methane gas, and our understanding of hydraulic fracturing activity in each of the eleven basins reviewed.

ES-2 What Is Hydraulic Fracturing?

Figure ES-2 illustrates a typical hydraulic fracturing event within a coalbed methane well. This diagram shows the fracture creation and propagation, as well as the proppant placement and fracturing fluid recovery stages.

A hydraulically created fracture acts as a conduit in the rock or coal formation that allows the oil or coalbed methane (one source of natural gas) to travel more freely from the rock pores to the production well that can bring it to the surface.

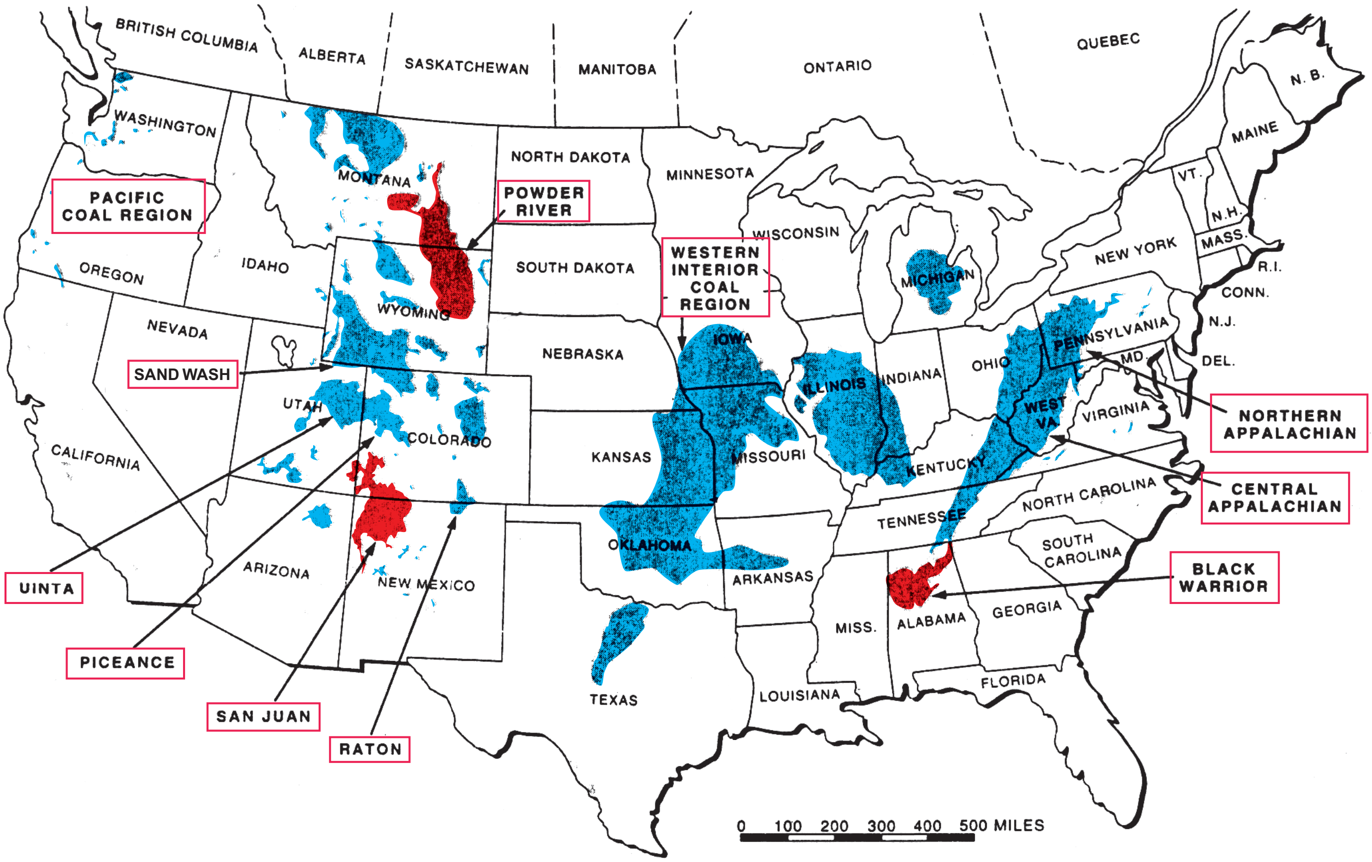
In the case of coalbed methane production, the gas is trapped in tiny, disconnected clusters of fractures (called "cleats") within a coal layer. The coal layer is typically sandwiched between

Table ES-1. U.S. Coal Basins Production Statistics and Activity Information

Basin	*Number of Producing Wells (Year 2000)	*Production of CBM in Billions of Cubic Feet (Year 2000)	Does Hydraulic Fracturing Occur?
San Juan	3,051	925	Yes
Black Warrior	3,086	112	Yes
Piceance	50	1.2	Yes
Uinta	494	75.7	Yes
Powder River	4,200	147	Yes (in the past)
Central Appalachian	1,924	52.9	Yes
Northern Appalachian	134	1.41	Yes
Western Interior	420	6.5	Yes
Raton Basin	614	30.8	Yes
Sand Wash	0	0	Yes (in the past)
Pacific Central	0	0	Yes (in the past)

*Data provided by GTI and EPA Region Offices

Figure ES-1. Locus Map of Major U.S. Coal Basins



layers of dense rock, such as shale, sandstone or limestone, which prevents the coalbed methane from migrating up and away from the coal. To extract the coalbed methane, a production well is drilled through the rock layers to intersect the coal seam containing the gas. Next, a fracture must be created in the coal seam to intersect the tiny, gas-bearing fractures and create a pipeline through which the coalbed methane can travel to the well so it can be brought to the surface.

To create such a fracture, a thick, water-based fluid is pumped into the coal seam at a gradually increasing rate. At a certain point, the coal seam will not be able to accommodate the fluid as quickly as it is being injected. When this occurs, the pressure is high enough that a fracture is created. A propping agent, usually sand (commonly known as "proppant"), is pumped into the fracture so that when the pumping pressure holding the fracture open is released, the fracture does not close completely because the proppant is "propping" it open. The resulting fracture filled with proppant is a conduit through which coalbed methane trapped in the formation can flow to the well.

Production begins when pumping of the well begins. Ground water is produced from the coal seam, decreasing the pressure and allowing methane to de-sorb from the coal matrix itself (Gray, 1987). Contrary to conventional gas production, the percentage of water produced declines with increasing coalbed methane production. In some basins, huge volumes of ground water are produced from the production well.

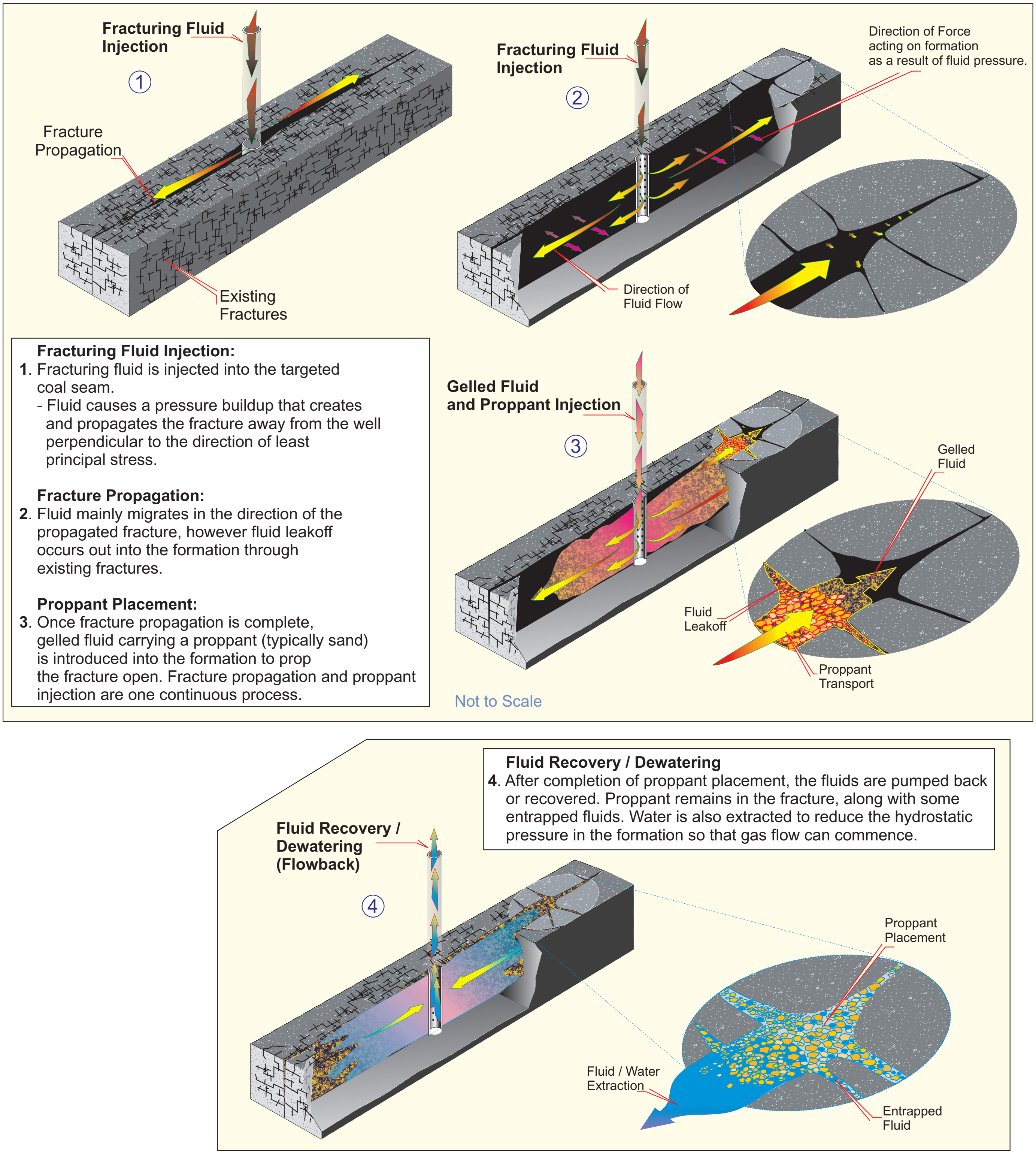
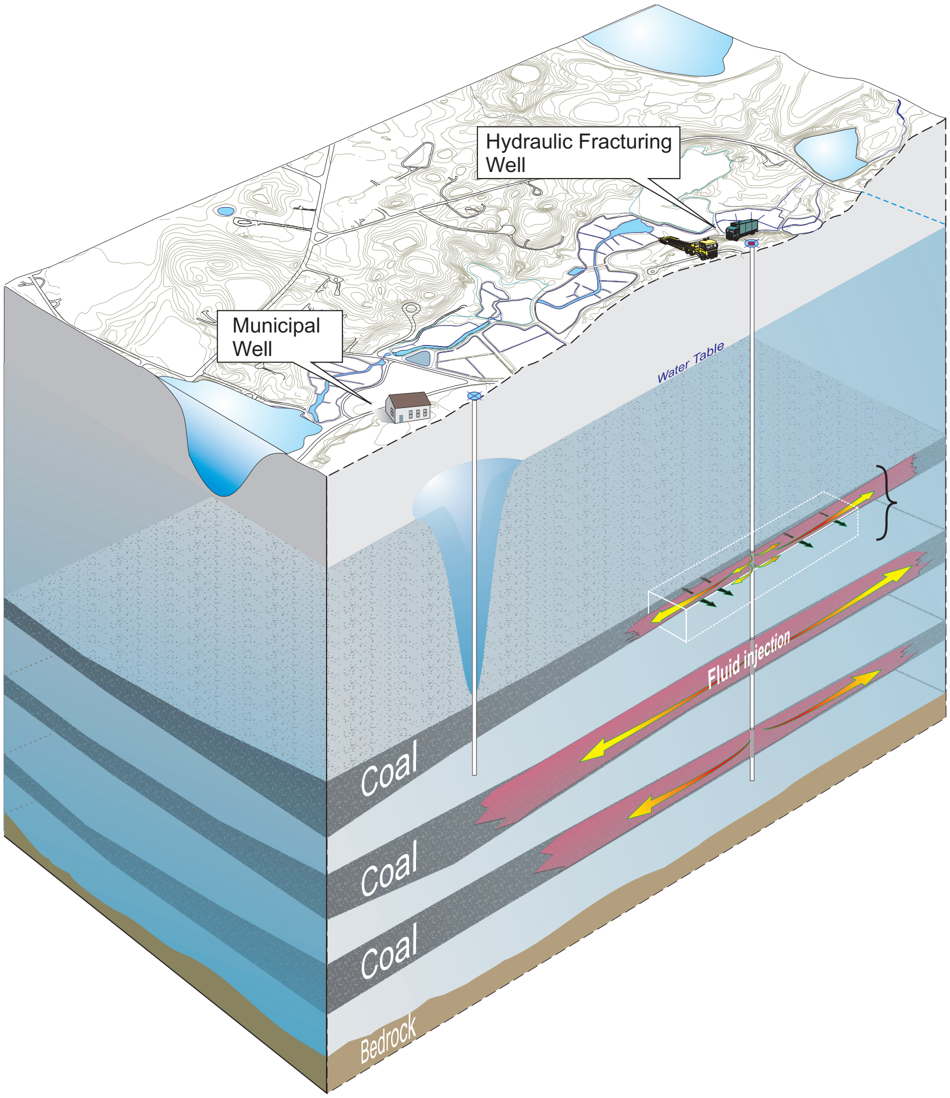
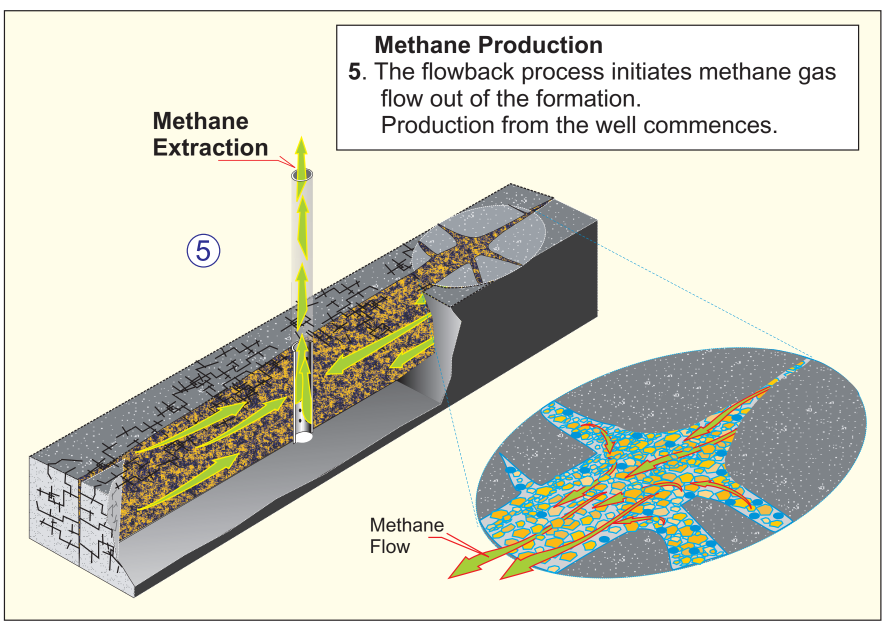


Figure ES-2. A Graphical Representation of the Hydraulic Fracturing Process in Coalbed Methane Wells


Hydraulic Fracturing
Well
Municipal
Well
Water Table
Fluid injection
Coal
Coal
Coal
Bedrock


Methane Production
5. The flowback process initiates methane gas
flow out of the formation.
Production from the well commences.
Methane
Extraction
5
Methane
Flow

ES-3 Why Is EPA Evaluating Hydraulic Fracturing?

EPA's Underground Injection Control (UIC) Program is authorized by the Safe Drinking Water Act (SDWA) to protect public health from threats arising from contamination of USDWs resulting from underground injection activities. Underground injection is the subsurface emplacement of fluids through a well bore. However, SDWA does not authorize EPA to regulate oil and gas production practices.

A USDW is defined as an aquifer or it's portion that:

A.

1. *supplies any public water system;*

or

2. *contains sufficient quantity of ground water to supply a public water system; and*
   i. *currently supplies drinking water for human consumption; or*
   ii. *contains fewer than 10,000 milligrams per liter (mg/L) total dissolved solids (TDS);*

and

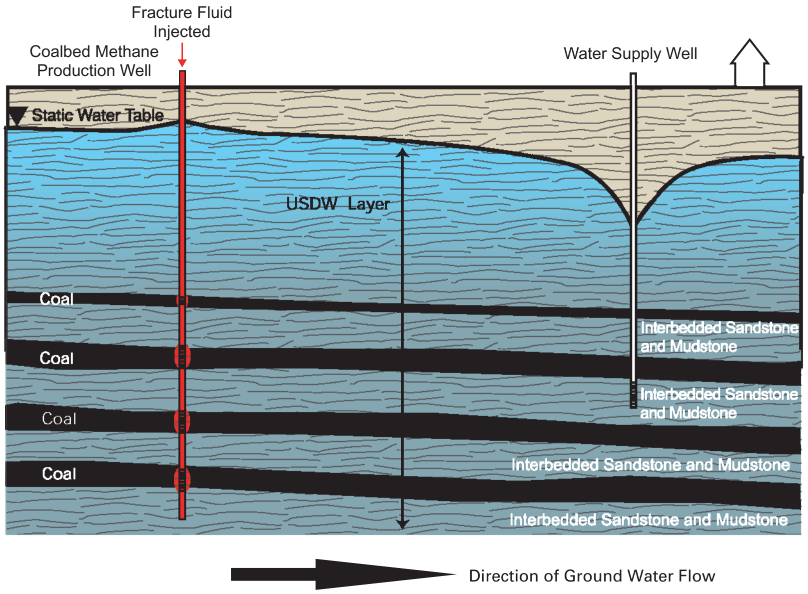
B. *is not an exempted aquifer.*

Although aquifers with greater than 500 mg/L TDS are rarely used for drinking water supplies, it is believed that imposing protection for waters with less than 10,000 mg/L TDS will ensure an adequate supply (through treatment) for present and future generations.

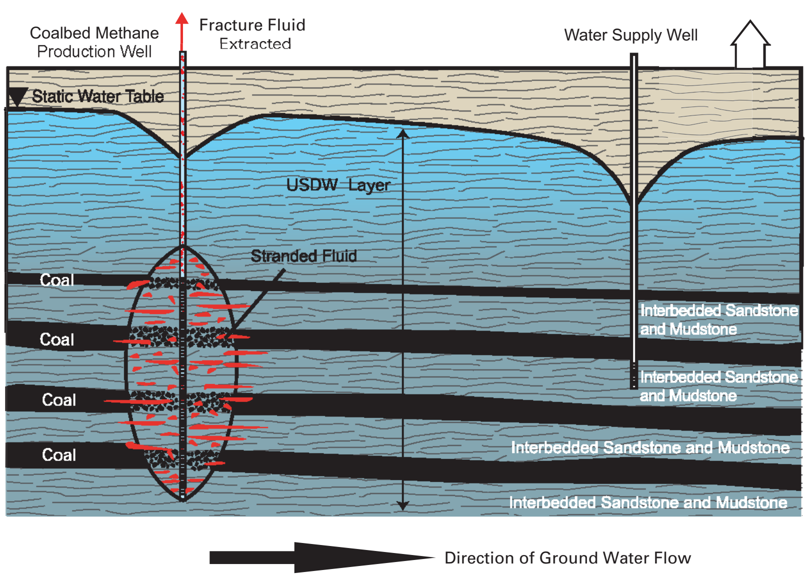
EPA initiated the hydraulic fracturing study in response to concerned citizens and the 11th Circuit Court's decision in LEAF v. EPA, 118F.3d 1467, which ruled that the State of Alabama must regulate hydraulic fracturing in order to retain authority of its State UIC Program. Members of Congress also wanted EPA to collect more information to evaluate any public health risks associated with hydraulic fracturing.

Figure ES-3. Direct Fluid Injection into a USDW (Coal within USDW)

Step 1:
Fracture Fluid is Injected into Coalbed Seams

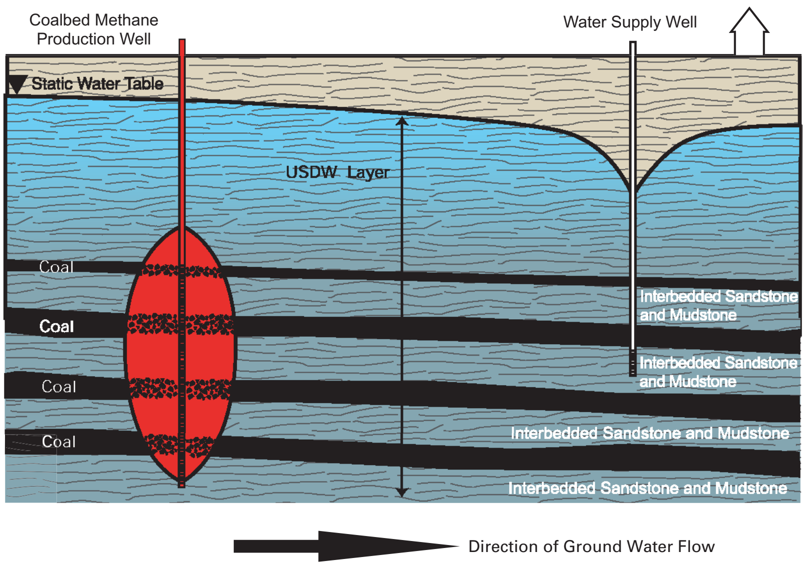


Step 3:
Fluid Stranded as Production Resumes

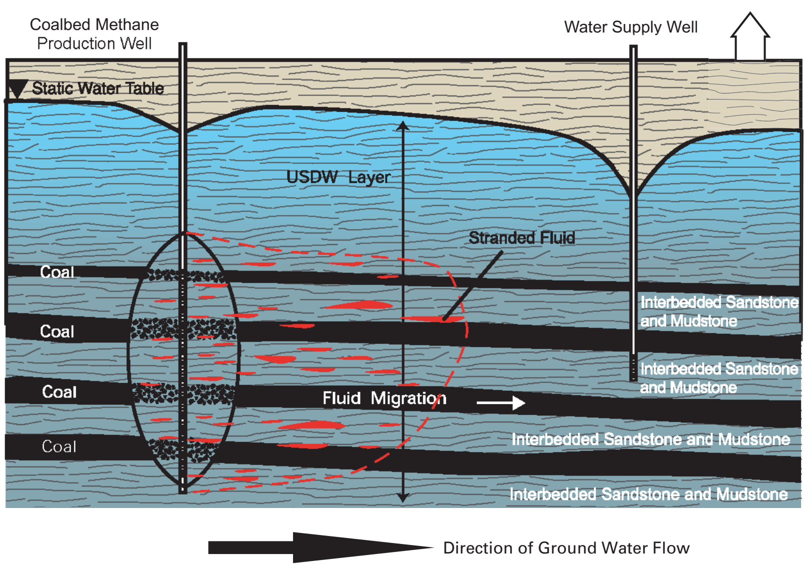


This study is narrowly focused to address hydraulic fracturing of CBM wells. It does not address all hydraulic fracturing practices, because (1) the 11th Circuit Court's decision was specific to CBM production; (2) CBM wells tend to be more shallow and closer to USDWs than conventional oil and gas production wells (1,000s of feet below ground surface [bgs] rather than 10,000s of feet bgs); and (3) EPA has not heard concerns from citizens regarding any other type of hydraulic fracturing. The study also does not address other concerns surrounding CBM production such as ground water removal or production water discharge

Step 2:
Fracture Created



Step 4:
Stranded Fluid Migration



ES-4 What Was EPA's Project Approach?

EPA designed the hydraulic fracturing study to have three possible phases, narrowing the focus from general to more specific as findings warrant. This report describes the findings from the Phase I efforts, a limited-scope assessment of potential threats posed from hydraulic fracturing using existing information.

The goal of EPA's hydraulic fracturing Phase I study is to determine if a threat to public health as a result of USDW contamination from hydraulic fracturing exists, and if so, is high enough to warrant further study. The threat to public health from USDW contamination was defined by the presence or absence of documented contamination cases stemming from hydraulic fracturing, or a clear immediate contamination threat to drinking water wells.

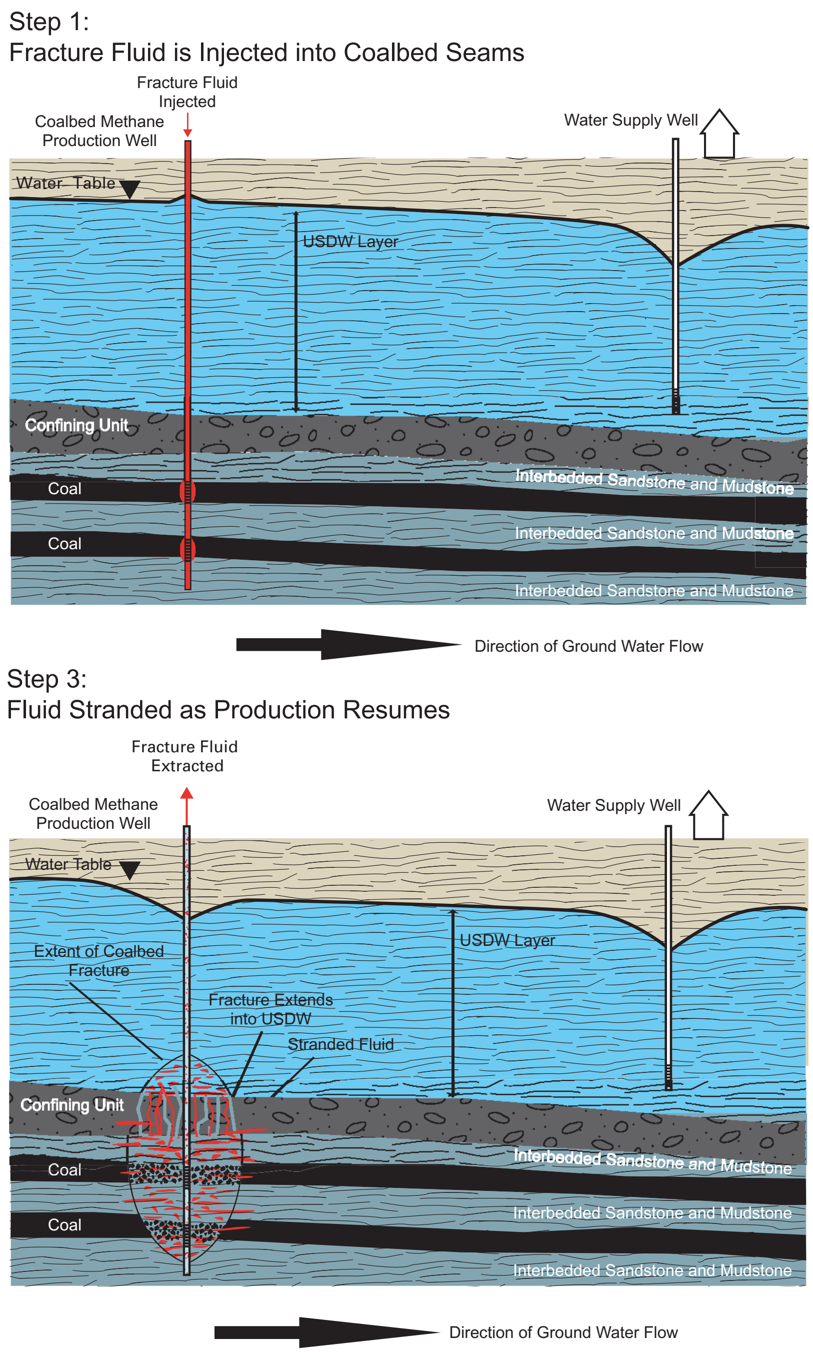
EPA's approach for evaluating the threat to public health was to review claimed incidents of drinking water well contamination as well as evaluate the theoretical potential for hydraulic fracturing to impact drinking water wells. We evaluated two potential mechanisms, illustrated in Figures ES-3 and ES-4, by which hydraulic fracturing may threaten USDWs: (1) the injection of fracturing fluids directly into a USDW, and (2) the creation of a hydraulic communication through a confining layer between the target coalbed formation and adjacent USDWs located either above or below.

ES-5 How Do Fractures Grow?

In many coalbed methane-producing regions, the target coalbeds occur within USDWs, and the fracturing process injects stimulation fluids directly into the USDWs. In other production regions, target coalbeds are adjacent to the USDWs that exist either higher or lower in the geologic section. Vertical fracture heights in coalbeds have been measured in excess of 500 feet and lengths can reportedly reach up to 1,500 feet. Fracture heights vary widely depending on the basin geology. For instance, in the Central Appalachian basin, fracture heights can be as small as two feet and lengths are typically in the range of 200 to 300 feet from the well bore (Halliburton, Inc., 2001). Hydraulic fracturing in coalbed methane formations in the Black Warrior basin can create fractures that are taller than they are long depending on the number of coal seams targeted and the strength of the intervening layers (Morales et al., 1990; Zuber et al., 1990; Holditch et al., 1989; Palmer et al., 1991, 1991a, 1993). The potential exists for fractures to extend from coalbeds into adjacent USDWs, which could increase communication between stratigraphic sections. Fractures generally will not penetrate confining layers separating coalbeds and overlying aquifers.

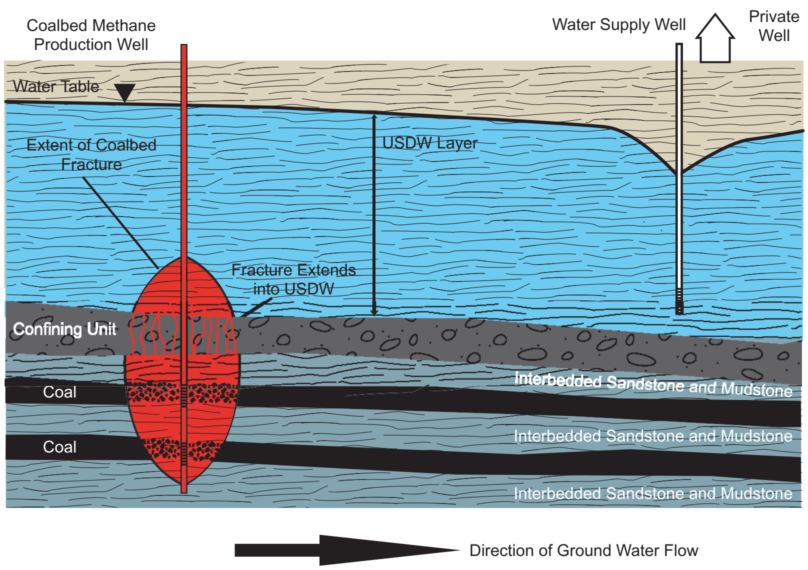
Once fracturing fluids are injected, either directly or indirectly, local geologic conditions may interfere with their

Figure ES-4. Fracture Creates Connection to USDW

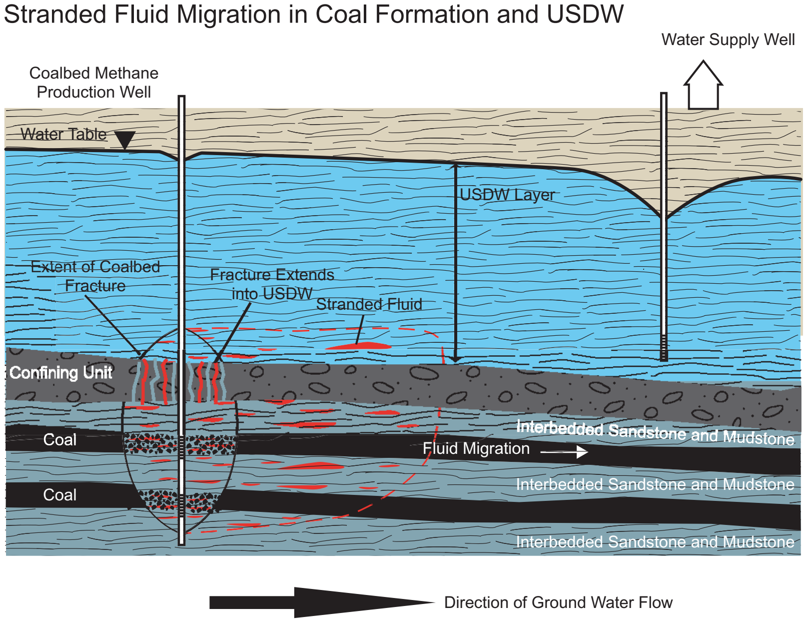


complete recovery. This may result in fracturing fluids being "stranded" in a USDW. Subsequent coalbed methane production creates a flow back regime that should contain ground water flow within the zone of influence surrounding the well. Any fluids not captured during production are presumably trapped due to low permeability within the formation. Low permeability limits ground water flow in both directions – toward the production well, which pulls ground water toward it and away from the production well.

Step 2:
Fracture Created (Breaking Through Confining Unit)



Step 4:
Stranded Fluid Migration in Coal Formation and USDW



The extent of a fracture is controlled by the characteristics of the geologic formation, the fracturing fluid type used, the pumping pressure, and the depth at which the fracturing is being performed. The fracture initiates from the well and extends out as two separate wings in opposite directions. Whether the fracture grows higher or longer is determined by the surrounding rock properties. A hydraulically created fracture will always take the path of least resistance through the coal seam and surrounding formations.

ES-6 What Is In Hydraulic Fracturing Fluids?

Fracturing fluids consist of primarily water or inert foam, such as nitrogen or carbon dioxide. Fluids also usually contain additives designed to improve performance of the fluid. Components of fracturing fluids are stored and mixed on site (Figures ES-5 and ES-6 show fluids stored in tanks at CBM well locations.) Table ES-2 lists additives available and any constituents of concern that may be in the additives. This information was obtained from material safety data sheets (MSDS) by EPA. Diesel fuel is the additive which contains most of the constituents of concern. It is used as an alternative to a water-based polymer gel. Much more gel can be dissolved in diesel as compared to water, reducing the cost required to transport the fracturing fluids. Water and any additives are typically pumped from the storage tanks to a manifold system placed on the production wells where they are mixed and then injected into the coal formation (Figure ES-6). Coalbed fracture treatments typically use 50,000 to 350,000 gallons of various fracturing fluids, and from 75,000 to 320,000 pounds of sand as proppant (Holditch et al., 1988 and 1989; Jeu et al., 1988; Hinkel et al., 1991; Holditch, 1993; Palmer et al., 1991, 1993, and 1993a). The volumes of constituents of concern and the ultimate concentration at which they are injected into the ground vary, but chemical additives make up only a small fraction of the overall fluid mixture. EPA estimated the concentrations of chemicals of concern in fracturing fluids at the point of injection using mid-range volumes reported by service companies. Table ES-3 presents the estimated concentrations and compares them to drinking water or ground water standards.

Studies observed that for fracture stimulations in conventional production formations, 25 to 65 percent of fracturing fluids are recovered during flowback (Mukhergee et al. 1995; Samuel et al. 1997; Willberg et al. 1997 and 1998). In a study specific to coalbed methane production, Palmer et al. (1991a) reported a 61 percent recovery of fracturing fluids after 20 days of production and projected that 20 to 30 percent would remain in the formation. To inform our decision, EPA estimated the concentrations of constituents of concern at the edge of a fracture considering only dilution effects and assuming 60 percent of fluid was recovered. We estimated concentrations decreased to 30 times less than those at point of injection – a significant drop at a relatively short distance from the production well. Any constituent of concern would have to migrate long distances, both vertically and horizontally, before reaching an exposure point.

Figure ES-5. The fracturing fluids are stored on site in large, upright storage tanks and in truck-mounted tanks.

Methane production requires the removal of ground water; thus, in active coalbed methane wells the lowest pressure is typically in the CBM production well. Ground water will flow in the direction of the lowest pressure. This pressure dynamic should prevent un-recovered fracturing fluids from migrating beyond the influence of the CBM well.

Figure ES-6. The fracturing fluids, additives, and proppant are pumped from the storage tanks to a manifold system placed on the wellhead where they are mixed just prior to injection.

ES-7 Are Coalbeds Located within USDWs?

EPA reviewed the geology of eleven basins to determine if coalbeds are co-located with USDWs and to understand the coalbed methane activity in the area. If coalbeds are located within USDWs, then any fracturing fluids injected into coalbeds have the potential to contaminate the USDW. As described previously, a USDW is not necessarily currently used for drinking water and may contain ground water not suitable for drinking without treatment. EPA found that ten of the eleven basins likely lie, at least in part, within USDWs. Table ES-4 identifies coalbed basin locations in relation to USDWs, and summarizes evidence used as the basis for the conclusions.

ES-8 Did EPA Find Any Cases of Contaminated Drinking Water Wells Caused by Hydraulic Fracturing in CBM Wells?

EPA reviewed studies and follow-up investigations conducted by State oil and gas agencies in response to citizen reports that CBM production resulted in water quality and quantity incidents. EPA found no confirmed cases of drinking water well contamination or water loss as the result of the hydraulic fracturing process.

EPA received reports of drinking water well problems associated with coalbed methane development (see Table ES-5) from:

- San Juan Basin (Colorado and New Mexico)
- Powder River Basin (Wyoming and Montana)
- Black Warrior Basin (Alabama)
- Central Appalachian Basin (Virginia and West Virginia).

Table ES-2. Summary of MSDSs[1] for Hydraulic Fracturing Fluid Additives

Product	Hazards Information	Toxicological Information	Ecological Information
Linear gel delivery system	-Harmful if swallowed -Combustible	- Chronic effects/Carcinogenicity - Contains diesel, a petroleum distillate (known carcinogen) - Causes eye, skin, respiratory irritation - Can cause skin disorders - Can be fatal if ingested	- Slowly biodegradable
Water gelling agent	- None	- May be mildly irritating to eyes	- Biodegradable
Linear gel polymer	- Flammable vapors	- Can cause eye, skin and respiratory tract irritation	- Not determined
Linear gel polymer slurry	- Causes irritation if swallowed - Flammable	- Carcinogenicity – Possible cancer hazard based on animal data; diesel is listed as a category 3 carcinogen in EC Annex I - May cause pain, redness, dermatitis	- Patially biodegradable
Crosslinker	-Harmful if swallowed -Combustible	-Chronic effects/Carcinogenicity D5 may cause liver, heart, brain reproductive system and kidney damage, birth defects (embryo and fetus toxicity) -Causes eye, skin, respiratory irritation -Can cause skin disorders and eye ailments	- Not determined
Crosslinker	- may be mildly irritating to eyes and skin - may be mildly irritating if swallowed	- May be mildly irritating	- Partially biodegradable - Low toxicity to fish
Foaming agent	- Harmful if swallowed - Highly flammable	- Chronic effects/Carcinogenicity – May cause liver and kidney effects - Causes eye, skin, respiratory irritation - Can cause skin disorders and eye ailments	- Not determined
Foaming agent	- Harmful if swallowed or absorbed through skin	- May cause nausea, headache, narcosis - May be mildly irritating	- Harmful to aquatic organisms
Acid treatment - hydrochloric acid	- May cause eye, skin and respiratory burns - Harmful if swallowed	- Chronic effects/Carcinogenicity – Prolonged exposure can cause erosion of teeth - Causes severe burns - Causes skin disorders	- Not determined
Acid treatment - formic acid	- May cause mouth, throat, stomach, skin and respiratory tract burns - May cause genetic changes	- May cause heritable genetic damage in humans - Causes severe burns - Causes tissue damage	- Not determined
Breaker Fluid	-May cause respiratory tract, eye or skin irritation - Harmful if swallowed	- May cause redness, discomfort, pain, coughing, dermatitis	- Not determined
Microbicide	- May cause eye and skin irritation	- Chronic effects/Carcinogenicity – Not determined - Can cause permanent eye damage, skin disorders, abdominal pain, nausea, and diarrhea if ingested	- Not determined
Biocide	- Causes severe burns - Harmful if swallowed - May cause skin irritation - May cause allergic reaction upon repeated skin exposure	-Harmful if swallowed; large amounts may cause illness - Irritant; may cause pain or discomfort to mouth, throat, stomach; may cause pain, redenss, dermatitis	- Not determined
Acid corrosion inhibitor	- May cause eye and skin irritation, headache, dizziness, blindness and central nervous system effects - May be fatal if swallowed - Flammable	- Chronic effects/Carcinogenicity – may cause eye, blood, lung, liver, kidney, heart, central nervous system and spleen damage - Causes severe eye, skin, respiratory irritation - Can cause skin disorders	- Not determined
Acid corrosion inhibitor	- Cancer hazard (risk depends on duration and level of exposure) - Causes severe burns to respiratory tract, eyes, skin - Harmful if swallowed or absorbed through the skin	- Carcinogenicity – Thiourea is known to cause cances in animals, and possibly causes cancer in humans - Corrosive - short exposure can injure lungs, throat, and mucous membranes; can cause burns, pain, redness swelling and tissue damage	- Toxic to aquatic organisms - Patially biodegradeable

[1] MSDS = Material Safety Data Sheets, lists of hazardous chemical constituents in industrial products.
They provide both workers and emergency personnel with the proper procedures for handling or working with a particular substance.
MSDS's include information such as physical data (melting point, boiling point, flash point etc.), toxicity, health effects, first aid, reactivity, storage, disposal, protective equipment, andspill/leak procedures.

Table ES-3. Estimated Concentrations at the Point of Injection of Constituents of Concern in Hydraulic Fracturing Fluids

Product	Chemical Composition of Existing Products	Concentrations of Interest (ug/L)	
	Chemical Compound	Injection Concentration	MCL or RBC or MCP
Linear gel delivery system	guar gum derivative		
	diesel		
	benzene	313.20	5.00
	toluene	522.00	1,000.00
	ethylbenzene	522.00	700.00
	xylene	522.00	10,000.00
	napthalene	14,094.00	20.00
	1-methylnapthalene	71,340.00	20 / 6,000
	2-methylnapthalene	34,974.00	121.67
	dimethylnapthalenes	270,570.00	na
	trimethylnapthalenes	160,080.00	na
	fluorenes	31,320.00	2,190.00
	phenanthrenes	7,830.00	300 / 50
	aromatics	574,200.00	200 / 30,000
Water gellling agent	guar gum		
	water	495,049.50	na
	fumaric acid	132,337.87	na
Linear gel polymer	fumaric acid	529,351.49	na
	adipic acid	366,257.43	na
Gelling agents (BLM Lists)	benzene		5.00
	ethylbenzene		700.00
	methyl tert-butyl ether		2.64
	napthalene		20.00
	polynuclear aromatic hydrocarbons (PAHs)		na
	polycyclic organic matter (POM)		na
	sodium hydroxide		na
	toluene		1,000.00
	xylene		10,000.00
Crosslinker	boric acid	170,998.00	na
	ethylene glycol	285,788.42	73,000.00
	monoethanolamine	na	na
Crosslinker	sodium tetraborate decahydrate	na	na
Crosslinkers (BLM Lists)	ammonium chloride		na
	potassium hydroxide		na
	zirconium nitrate		na
	zirconium sulfate		na
Foaming agent	isopropanol	234,945.16	na
	salt of alkyl amines	na	na
	diethanolamine	na	na
Foaming agent	ethanol	236,081.75	na
	2-butoxyethanol	269,641.08	na
	ester salt	na	na
	polyglycol ether	na	na
	water		na
Foamers (BLM Lists)	glycol ethers		na
Acid treatment - hydrochloric acid	hydrochloric acid	na	na
Acid treatment - formic acid	formic acid	na	73,000.00
Breaker Fluid	diammonium peroxidisulphate	na	na
Breaker Fluids (BLM Lists)	ammonium persulfate		na
	ammonium sulphate		na
	copper compounds		1,460.00
	ethylene glycol		na
	glycol ethers		na
Microbicide	2-bromo-2nitro1,3-propanediol	na	na
Biocide	2, 2-dibromo-3-nitrilo propionamide	na	na
	2-bromo-3-nitrilopropionamide	na	na
Bactericides	polycyclic organic matter (POM)	na	na
	polynuclear aromatic hydrocarbons (PAHs)	na	na
Acid corrosion inhibitor	methanol	236,070,000.00	18,250.00
	propargyl alcohol	47,425,000.00	na
Acid corrosion inhibitor	pyridinium, 1-(phenylmethyl)-, ethyl methyl derivitives, ch	na	na
	thiourea	210,750,000.00	na
	propan-2-ol	39,275,000.00	na
	poly(oxy-1,2-ethanediyl)-nonylphenyl-hydroxy	na	na
	water		na

(green) = 2 numbers given (1. Drinking water standard 2.Groundwater discharging to surface water standard)

(yellow) = Exceeds regulatory standard

MCL = Maximum Contaminant Level - The highest level of a contaminant that is allowed in drinking water.

RBC = EPA's Risk Based Concentration Tables. www.epa.gov/reg3hwmd/risk/index.html, developed by Region 3 (serving: Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, West Virginia)

MCP = Massachusetts Contigency Plan - Risk-based ground water standards for drinking water protection - chosen because Massachusetts has developed standards for many constituents in deisel fuel.

Table ES-4. Evidence In Support Of Coal-USDW Co-Location In U.S. Coal Basins

Basin	Is coal found within the USDW?	Explanation and/or evidence
San Juan	Yes	A large area of the Fruitland system produces water containing less than 10,000 mg/L TDS, the water quality criteria for a USDW. Analyses taken from a selected coal well area show that the majority of wells (16 of 27 wells) produce water containing less than 10,000 mg/L TDS (Kaiser et al., 1994).
Black Warrior	Yes	Almost all waters of the Pottsville aquifer contain less than 10,000 mg/L TDS, and most waters in the Pottsville flow systems contain less than 3,000 mg/L TDS, even within the deeper, methane-target coal seams such as the Mary Lee beds (Pashin et al., 1991; Pashin and Hinkle, 1997).In the early 1990's, several authors reported fresh water production from coalbed wells at rates up to 30 gallons per minute (summarized in Pashin et al., 1991; Ellard et al., 1992).
Piceance	Unlikely	The stratigraphic separation between the coal gas bearing zone and the lower aquifer system in the Green River Formation is approximately 6,400 feet. The major coalbed methane target, the Cameo-Wheeler-Fairfield coal zone lies roughly 6,000 feet below the ground surface in a large portion of the basin (Tyler et al., 1998). A composite water quality sample taken from 4,637 to 5,430 feet deep within the Cameo Coal Group in the Williams Fork Formation exhibited a TDS level of 15,500 mg/L (Graham, CDWR, personal communication 2001). The produced water from coalbed methane extraction in the Piceance Basin is of such low quality that it must be disposed of in evaporation ponds or re-injected into the formation from which it came, or at even greater depths (Tessin, 2001).
Uinta	Likely	Production waters from coal seams at the higher elevation Castlegate Field within the Blackhawk Formation appear to have TDS levels of about 5,000 mg/L (Quarterly Review, 1993).
Powder River	Yes	A report prepared by the US Geological Survey showed that samples of water co-produced from 47 CBM wells in the Powder River Basin all had a TDS of less than 10,000 mg/L (Rice et al., 2000). The water produced by coalbed methane wells in the Powder River Coal Field commonly meets drinking water standards. In fact, production waters such as these have been proposed as a separate or supplemental source for municipal drinking water in some areas (DeBruin et al., 2000).
Central Appalachian	Likely	Depths of coal groups are coincident with fresh water in at least two of the states within the overall basin (Kelafant et al., 1988; Wilson, 2001; Foster, 1980; Hopkins, 1966 and USGS, 1973). Anecdotal information suggests that private wells in Virginia are screened within coal seams (Wilson, VDMME, 2001).
Northern Appalachian	Yes	The depth of each coal group within the basin is coincident with the depths of USDWs (Kelafant et al., 1988; Platt, 2001; Foster, 1980; Hopkins, 1996; USGS, 1973; Sedam and Stein, 1970; USGS, 1971; Duigon, 1985). Water quality data from eight historic Northern Appalachian Coal Basin projects show that TDS levels were below 10,000 mg/L (Zebrowitz et al., 1991).
Western Interior *Arkoma*	Yes (in Arkansas) Unlikely (in Oklahoma)	The depths of coal beds within the State of Arkansas are coincident with depths to fresh water (Andrews et al., 1998; Cordova, 1963; Friedman, 1982; Quarterly Review, 1993). Based on maps provided by the Oklahoma Corporation Commission (2001) as to the depths of the 10,000 mg/L of TDS ground water quality boundary in Oklahoma, the location of coalbed methane wells and USDWs would most likely not coincide in Oklahoma. This is based on depths to coals typically greater than 1,000 feet (Andrews et al, 1998) and depths to the base of the USDW typically shallower than 900 feet (OCC Depth to Base of Treatable Water Map Series, 2001).
Cherokee	Yes	The depths of coal beds within the State of Kansas are coincident with depths to fresh water (Quarterly Review, 1993; McFarlane, 2001; DASC, 2000).
Forest City	Unlikely	The shallow thickness of the aquifer suggests that there is significant separation from the deeper coalbeds within the basin (Bostic et al, 1993; DASC, 2001; Condra and Reed, 1959; Flowerday et al., 1998).
Raton Basin	Yes	Water quality results from coalbed methane wells in the Raton Basin demonstrate TDS content of less than 10,000 mg/L. Nearly all wells surveyed show a TDS of less than 2,500 mg/L, and more than half had TDS of less than 1,000 mg/L (Nat. Wat. Sum., 1984).
Sand Wash	Yes	Two gas companies produced water from coals that showed TDS levels below 10,000 mg/L. At Craig Dome in Moffat County, Cockrell Oil Corporation drilled 16 coalbed methane wells. The wells yielded large volumes of fresh water with TDS <1,000 mg/L (Colorado Oil and Gas Commission web site, 2001). Fuelco was operating 11 wells along Cherokee arch. Water pumped from the wells contained 1,800 mg/L of TDS and was discharged to the ground with a NPDES permit (Quarterly Review, 1993).
Pacific Central	Yes	Data demonstrating the co-location of a coal seam and a USDW was found for Pierce County. Water quality information from four gas test wells indicates TDS levels between 1330 and 1660 mg/L, well below 10,000 mg/L (Dion, 1984). Wells in the Basalts commonly yield 150 to 3,000 gallons per minute. Total dissolved solids in the water produced generally range from 250 to 500 mg/L (Dion, 1984).

Water quantity complaints are the most predominant cause for complaint by private well owners. EPA received reports from concerned citizens from each area with significant coalbed methane development. Taken on a case-by-case basis, investigations of water well contamination incidents conducted by the states do not provide evidence that hydraulic fracturing of CBM wells has impacted drinking water wells. Several other factors may contribute to ground water problems such as various aspects of resource development, naturally-occurring conditions, population growth and historical practices.

ES-9 What Are EPA's Conclusions and Recommendations?

EPA's approach for evaluating the threat to public health was an extensive information collection and review of empirical and theoretical data.

Based on the information collected, the threats posed by hydraulic fracturing of CBM wells to USDWs are low, and do not justify additional study. A Phase II effort would not likely provide any new information that would redirect the Phase I findings – those being a lack of contamination incidents and low potential for hydraulic fracturing to threaten human health through the contamination of USDWs. Therefore, the apparent risk to public health from hydraulic fracturing is not compelling enough to warrant expending resources on a Phase II effort.

Finally, it is important to note that States with primacy for their UIC programs enforce and have the authority to place controls on any injection activities that may threaten USDWs. With the expected increase in CBM production, additional data collection may become valuable in the future, if development leads to injection of fracturing fluids into USDWs that are simultaneously used as drinking water sources. The Agency is committed to working with states to collect relevant data to monitor this issue.

Table ES-5. Summary of Reported Incidents that Associate Water Quality/Quantity with Coalbed Methane (CBM) Activity

Basin	Water Contamination Associated with Methane	Water Contamination Associated with Fracturing Fluids
San Juan Basin (New Mexico, Colorado)	• Increased methane and hydrogen sulfide in water wells, pumphouses, and homes. • Claims of data showing methane concentrations in wells increased by 1000 ppm. • Improperly abandoned wells lead to methane migration from deep coal seams to shallow soils.	Information not available
Powder River (Wyoming, Montana)	• Methane causes drinking water to froth and bubble.	Information not available
Black Warrior (Alabama)	• Drinking water well was hissing due to a high concentration of methane gas. Water also had a strong, unpleasant odor.	• Citizen believes drinking water well became contaminated with a brown, slimy, petroleum-smelling fluid after recovered fracturing fluid drained from a CBM well site to an area near this homeowner's house.
Central Appalachian (Virginia, West Virginia)	• Well water contaminated by methane gas had bad taste and odor.	• Fish kills believed to be a result of fracturing fluid discharged into streams. • VA DMME states that soap bubbles in residential water fixtures are linked with production well drilling.

Water Contamination Reported Without Specific Mention of CBM Activity	Water Depletion or Loss Associated with CBM Activity	Non-Water Related Impacts Associated with CBM Activity
• Appearance of anaerobic bacteria in wells and transient appearance of particulates. • Black water believed to be due to pulverized coal. • Cloudy water with grayish sediment found 2 days after fracturing.	• Complaints of loss of water due to CBM development.	• Impacted vegetation.
Information not available	• Loss of water in wells from CBM development. • Aquifer dropped up to 200 feet in some areas.	• Discharged water creates artificial ponds and swamps not indigenous to region. • Coal ignites from lightning and creates underground fires that burn because of dewatered aquifer. This creates toxins and carcinogens that could contaminate water.
• Well water with milky white substance and strong odor. • Well water with black fines, globs of black jellied grease and smelled of petroleum. • Well water turned brown and had long, slimy tags of floating gunk.	Information not available	• Citizen believed recovered hydraulic fracturing fluid was allowed to run off-site. She noticed animal/plant life impacted.
• Private well contamination by oily films, soaps, iron oxides precipitates, black sediments, bad odor and taste, diesel fuel smells, and murky water. • Soap bubbles flowing from residential household fixtures. • Resident provided EPA with well water sample that was translucent with dark gray color and dark black sediments.	• Average of 10-12 complaints per year to Virginia Dept of Mines, Minerals, and Energy involve reports of water supplies diminishing or disappearing entirely. • Over 380 homes in Buchanan County without potable water as a result of CBM development.	• Residents develop rashes from showering. • Miner burned from acid that seeped into mine shaft.

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